PORTABLE CHEMICAL STERILIZER (PCS) FOR SURGICAL INSTRUMENTS

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ABSTRACT

A novel device called the Portable Chemical Sterilizer (PCS) has been developed for the rapid, safe, portable, power-free, and convenient sterilization of objects or surfaces contaminated with pathogenic microorganisms that cause foodborne illnesses, infections, and disease. The PCS relies on a novel chemical composition consisting of safe, easy-to-transport reagents. Adding water activates the chemical to controllably generate heat, steam, and the potent, broad-based biocidal agent chlorine dioxide (ClO_2) that eliminate foodborne pathogens (*Staphylococcus aureus*, *Escherichia coli*, *Listeria monocytogenes*) and bacterial spores of *Bacillus stearothermophilus*. The chemical reaction takes place inside specially configured prototype units to controllably sterilize contaminating microorganisms in as little as 30 minutes. Fundamentally, the sterilization process relies on the principles of chemical kinetics to control the rate of exothermic inorganic chemical reactions that produce heat and the disinfectant ClO_2 at rates compatible with achieving the inactivation of harmful microorganisms. The genesis of the PCS configurations and the results of microbiological validation are presented.

1. INTRODUCTION

Sterilizing objects or surfaces of equipment contaminated with pathogenic microorganisms is crucial for preventing the spread of foodborne illnesses or infectious diseases. The need for sanitization, disinfection, or sterilization is compounded in remote field conditions, where transporting electrical generators severely limits the availability of electrical power or transporting heavy containers containing hazardous chemical sterilants is disadvantageous. For example, Far-Forward Army Surgical Teams often rely on transporting contaminated surgical equipment with patient via aircraft back and forth to distant hospitals for sterilization in pressurized steam autoclaves. Thus, it is apparent that there is a need for alternative methods of sterilizing microbiologically contaminated items or equipment that functions on-site, is portable, and requires no exogenous sources of power, such as electricity or fuel.

We propose the Portable Chemical Sterilizer (PCS) as a specially configured, portable, and power-free device that exploits chemical energy released from safe, dry reagents to controllably generate, heat, steam, and the biocidal chemical agent chlorine dioxide (ClO_2). The conditions generated in this device act in concert to kill harmful microorganisms on contaminated object in minutes.

2. RESULTS

The PCS exploits two chemical reactions, either individually or in combination, to effect sterilization of contaminated objects. The first system is a scaled up version of the MRE heater (aka, the Flameless Ration Heater), which is based on the iron-activated magnesium-water chemical reaction, to generate heat (T > 121 °C) and steam to kill microorganisms (Fig 1).

Figure 1. Prototype I: an insulated pressure cooker

The second chemical reaction is the environmentally-friendly alternative chemical heater consisting of a halogen, reductant, and an effector to produce ClO_2 (see Figure 2). ClO_2 is an EPA-registered disinfectant that was used in the crisis response to the Anthrax (*Bacillus anthracis*) attacks in Washington, DC. When the PCS uses both the MRE heater and the alternative chemical heater together (the "standard composition"), large

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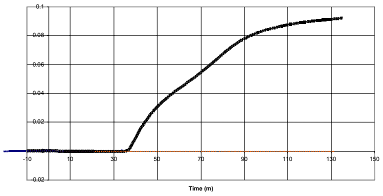

Figure 2. ClO_2 production by chemical reaction

quantities of heat, steam, and chlorine dioxide are produce that act in concert to effect the destruction of the contaminating microorganisms. In fact, the conditions of heat and humidity created inside the PCS intensify the effectiveness of ClO_2 as a lethal biocidal agent. In both cases, a 20-Liter pressure cooker modified with thermal insulation and internal shelving is required to accommodate the build up in temperature and pressure created by the MRE heater chemical reaction. Examples of sterilization with respect to bacterial vegetative cells and spores are compiled in Table 1.

Table 1. Microbial destruction in PCS using standard composition for 60 min.

	Initial CFU/mL	Final CFU/mL
B stearothermophilus spores	1.00×10^8	0.0
E. coli	1.20×10^7	0.0
L. monocytogenes	1.34×10^8	0.0

The environmentally-friendly ("green") alternative chemical heater can also act effectively to kill microorganisms without contributions from the MRE chemical heater. In this case, the chemical composition is modified slightly and the reaction produces copious quantities of ClO_2. Correspondingly, this chemical reaction system does not produce the high temperatures ($T < 55$ °C) or pressures chareacteristic of the Mg(Fe)-water chemical reaction. Consequently, the controlled generation of ClO_2 and mild heat in this case affords the opportunity to use lightweight, easy-to-transport, chemically resistant plastic as the construction materials for the PCS. The prototype II PCS (Fig. 3) consists of a

Figure 3. Production of ClO_2 by the alternative chemical heater in a 1 ft^3 plastic unit.

1 ft^3 plastic bucket that resists damage from chemicals and can accommodate a loose collection of microbiologically contaminated objects such as used surgical instruments.

The chemical composition can also be scaled up to run in larger plastic containers capable of accommodating an entire tray of microbiologically contaminated surgical instruments (Fig. 4). Additional modifications to the design in this case include a scrubber, which is a detachable device connected to the main unit through which excess ClO_2 gas flows post-sterilization, and which contains harmless reductants to deactivate the ClO_2 gas.

Figure 4. ClO_2 produced by the alternative chemical heater inside a large plastic unit. The white scrubber removes excess ClO_2 after sterilization is complete.

Converting the prototype to a plastic Pelican case (Fig. 5), an item that is currently used by many military units, and inserting appropriate modifications to ensure effectiveness, user safety, and environmental safety, the following design was developed that sterilizes in 30 min using approximately 300 grams of dry chemical reagents:

Figure 5. Pelican case prototype: 1) add reagents, 2) generate ClO_2, and 3) sterilized (easy as 1-2-3)!

3. CONCLUSIONS

The PCS harnesses two chemical reactions to generate *in situ* sufficient conditions of heat, steam, and the lethal biocidal agent ClO_2 to effect sterilization of microbiologically contaminated object in 30 minutes safely, conveniently, portably, and without electricity or other power sources. ClO_2 is a potent biocide that rapidly kills microorganisms. The maturation of this PCS technology will significantly enhance the operational capabilities of units such as Far-Forward Army Surgical Teams and promote portability, power-free, and nearly waterless decontamination in support of the Future Force Warrior using proven environmentally-friendly disinfectants.